which is 6½° above the freezing point. That other circumstances must be combined with the cold to produce frost, is evident from this also; on the higher parts of mountains, where it is absolutely colder than in the plains on which they stand, frosts do not appear so early by a considerable space of time in autumn and go off sooner in the spring than in the plains. I have known frosts so severe as to kill the hickory trees round about Monticello, and yet not injure the tender fruit blossoms then in bloom on the top and higher parts of the mountain, and in the course of forty years, during which it has been settled, there have been but two instances of a general loss of fruit on it, while in the circumjacent country the fruit has escaped but twice in the last seven years. The plants of tobacco, which grow from the roots of those which have been cut off in the summer, are frequently green here at Christmas. This privilege against the frost is undoubtedly combined with the want of dew on the mountains. That the dew is very rare on their higher parts, I may say with certainty from twelve years observations having scarcely ever, during that time, seen an unequivocal proof of its existence on them at all during summer. Severe frosts in the depth of winter prove that the region of dews extends higher in that season than the tops of the mountains, but certainly, in the summer season, the vapors by the time they attain that height are become so attenuated as not to subside, and form a dew when the sun retires.

One more extract from the Notes on the State of Virginia showing Jefferson's close observation of the optical phenomenon known as "looming," which is frequent at sea but rare on land; but as Jefferson says:

At Monticello it is familiar. There is a solitary mountain about 40 miles off in the south, whose natural shape, as presented to view there, is a regular cone, but by the effect of looming it sometimes subsides almost totally in the horizon, sometimes it rises more acute and more elevated, sometimes it is hemispherical, and sometimes its sides are perpendicular, its top flat and as broad as its base. In short, it assumes at times the most whimsical shapes, and all these perhaps successively in the same morning. The Blue Ridge of mountains comes into view in the northeast at about 100 miles distance, and approaching in a direct line passes by within 20 miles and goes off to the southwest. This phenomenon begins to show itself on these mountains at about 50 miles distance and continues beyond that as far as they are seen. I remark no particular state, either in the weight, moisture, or heat of the atmosphere, necessary to produce this. The only constant circumstances are its appearance in the morning only, and on objects at least 40 or 50 miles distant. In this latter circumstance, if not in both, it differs from the looming on the water. Refraction will not account for the metamorphosis. That only changes the proportions of the length and breadth, base and altitude, preserving the general outlines. Thus, it may make a circle appear elliptical, raise or depress a cone, but by none of its laws, as yet developed, will it make a circle appear a square, or a cone a sphere.

NOTES BY THE EDITOR.

METEOROLOGY IN THE PUBLIC SCHOOLS.

Among the improvements in methods of education none is more rational and practically successful than that which insists on requiring the pupils, from the youngest to the oldest, to observe natural phenomena and make their own personal records and deductions. For a century past the favorite field of "nature-study" has been that of botany, and a visitor to the best primary schools will find the children bringing in quantities of leaves, buds, and flowers, which they compare and study, and thus quicken their habits of observation and generalization. Almost equally attractive is the elementary study of the soils, rocks, and minerals. In regions where birds and insects are accessible these also afford fine objects for study. The whole tendency of modern pedagogy is to stimulate the study of nature in every field, especially those most easily accessible. In October, 1882, the present Editor had occasion to give a series of talks to the students of the Normal School in Washington, and to maintain that as we have the weather about us every day it constitutes an admirable subject for youthful observation and study. In accordance with the principles that were then taught at that Normal School it was necessary for each member of the class to record and analyze her own observations on the subject under consideration, in order, by this personal training, to obtain the experience that is necessary to successfully conduct the classes of children that must eventually come under her care. Accordingly, the present writer prepared an elementary printed form for the use of the class in which each member kept a personal diary of the weather, in so far as that could be done without instruments. Specimens of these diaries and an explanation of the whole system were exhibited at the New Orleans Exposition in December, 1884, in the division of pedagogy.

Subsequently the accomplished principal and founder of the Normal School at Washington (Miss Lucilla E. Smith) was called to take charge of a part of the work of the Training School for Teachers in Brooklyn, N. Y. In such a location where botany and geology are not so easily studied she again had occasion to advocate the observation and study of atmospheric phenomena as a means of training the perceptive faculties of the pupils. This idea, which was at first so novel, has been practically carried out during the past two years, and many have testified that not only the scholars but the teachers themselves have profited greatly by this drill. Each child is expected to keep a record of the wind and weather, and the discussions that take place are rapidly disabusing the children's minds of erroneous ideas that are widely disseminated. The trite weather sayings that have been current for centuries, and that have no real basis of fact, yet are handed down like myths and legends *viva voce*, from parent to child, are now daily brought to the test of actual experience, and a healthy stimulus is given to the study of nature. The children, and even the teachers, begin to wonder at the numerous erroneous notions formerly entertained and to admire the clearer vision that they are now rapidly attaining. This feature in the study of nature was advocated before the Brooklyn Institute in 1893, and the teaching of meteorology in the schools has since then received enthusiastic endorsement. Probably Miss Smith was the first in this country to introduce this study, first into the Normal School and then into the public schools of all the lower grades. The future development of meteorology in this country will largely depend upon the extent to which it is taught in the public schools. The special meteorologists of future generations will, undoubtedly, look back to the time when, as school children, their attention was first seriously directed to this study.

THE GENERAL CIRCULATION OF THE ATMOSPHERE.

On several occasions the Editor has in the MONTHLY WEATHER REVIEW enforced the principle that the important peculiarities of any season depend upon what is called the general circulation of the earth's atmosphere. That is to say, an unusual drought or a remarkable series of rains, or the so-called apparent secular change in the general climate of any locality is not at all to be considered as dependent, even to the slightest extent, upon the destruction of forests, the cultivation of the surface of the ground, the local evaporation, the presence of lakes or rivers, etc. Even great forest fires have been shown to have little influence on the subsequent weather. All these phenomena affect the air that is temporarily at the surface of the earth, but as soon as this air is raised and carried off into the cloud region, it is mixed with such a large mass of other air that its special influence becomes greatly diminished, and is felt, if at all, in some far distant region and at some distant time. It is very easily shown that the strong winds, and with them the temperature and dryness that we feel during midday, represent currents of air that are descending to the ground from regions far above us. This descent is due to several distinct causes. Formerly meteorologists spoke of the ascent of air heated by contact with the warm soil upon which the sun was shining, but now we must equally recognize the descent of colder air and its cooling by radiation, which is quite as important as the warming by insolation. Ascending currents may be caused by the action of the sunshine upon the upper surface of clouds, or by the condensation of the moisture and the evolution of heat within the clouds. Descending currents may be caused by the radiation from the surface of the clouds, or even from the dust contained in what is called ordinary clear air. In addition to the vertical interchange due to heat another special mechanism by which upper and lower layers of air are interchanged, is to be found in the fact that the lower horizontal currents by striking against obstacles are forced upward. The obstacle may be either a layer of air, or a gentle ocean shore, or the resistance of a high range of mountains. The obstacles encountered by the winds are quite as important as the influence of temperature and evaporation over land and water. If we consider the earth as a whole we find that over the so-called watery hemisphere the atmosphere near the surface of the ocean experiences resistances to motion, differences of temperature, and variations in moisture that are all far smaller than those experienced over the land that prevails on the continental half of the globe.

The study of the dynamics, that is to say, the theory of the motions of the atmosphere began by solving the simpler problems in which the earth's surface is regarded as a regular sphere having a uniform coefficient of friction or slip, or, perhaps, even no friction or resistance, but we must now proceed to the study of the influence of the larger rugosities of the surface, such as mountain ranges, plateaus, and continents, and that too without neglecting the variations of temperature and moisture.

For the same barometric gradient we find stronger horizontal winds but less vertical interchange over the ocean than over the land. If we draw isobars for the whole globe, we find areas of high and low pressure over the land and water so distributed along any small circle of latitude that we usually say the pressure varies with the seasons, and appears less over the warm regions and greater over the colder regions. If, however, we draw isobars for a surface that is 5,000 meters above sea level, which surface is, therefore, above almost all points of the Rocky Mountain Region and the Andes, and above the greater part of the Himalayas, and if we plot the motions of cirrus clouds in connection with these upper isobars, we are able to study another aspect of the combined influence of the temperature of the air and the resistance to its motion. At this level a single area of low pressure of an ovoidal shape surrounds either pole; the Antarctic area is quite symmetrical about the South Pole, but the Arctic area is by no means so with regard to the North Pole. Both the shape and the want of symmetry of the Arctic area varies from month to month and, of course, more so from day to day. These variations in the upper isobars result partly from broad features in the variable temperature and moisture, cloudiness and rain of the atmosphere below the level of this upper surface, but they depend still more directly upon the resistances which the lower air experiences as it moves over the land and the water, and on the inertia of the moving mass of air and the rotation of the whole atmosphere with the earth. Pressure depends in general not only upon the weight of the atmosphere above any point but upon the motion of the air at that very point itself, since this motion implies the introduction of centrifugal forces which act perpendicularly to the line of movement. It is proper to consider that upper atmosphere of the Northern Hemisphere is tending to move around and inward in accordance with the isobars at this upper level, but that in this movement it experiences resistances which force it to ascend slightly in some regions and to descend in others. When it strikes a coast line or very gentle slope the ascent is decided, but correspondingly gentle; when it strikes an abrupt coast line a portion is forced upward, while an important portion is forced downward and backward. The study of these upper isobars and isotherms and cloud movements brings into one general and homogenous system the phenomena that we observe at the surface of the ground and the most diverse phenomena in distant portions of the globe. Several illustrations of such connections have already been published in the REVIEW, and we have now to refer to a still more interesting case that has lately been worked out by Mr. John Eliot, meteorological reporter to the Government of India. (See Quarterly Journal Royal Meteorological Society, January, 1896, Vol. XXII, p. 1.)

During the years 1894-'95 the Government of India has published a daily weather chart, showing the chief features of the meteorology of southern Asia and the adjacent seas southward over the Indian Ocean to about 10° beyond the equator. The object of this publication has been to furnish the data for the proper study of the relation between the rains and winds of the cold weather season or the northeast monsoon period, as also the winds and rains of the southwest monsoon period or warm weather season. The climate of India has generally been considered as divisible into two seasons, the northeast monsoon in the colder half of the year and the southwest monsoon in the warmer half. Rains or snows of considerable agricultural importance occur during the colder half, but the principal rains are those of the southwest monsoon. The general reason for the well-marked seasonal systems of cold, dry northeast and warm, moist southwest winds has usually been found in the coldness of the air over India and Asia during the winter and its warmth during the summer. For some years past efforts have been made to predict the general character of the monsoon seasons from our knowledge of the conditions that caused it to be hot or cold over India and the countries to the northward. Such predictions were felt to be imperfect because it was evident that the atmosphere to the south of India and, therefore, over the ocean ought to be considered quite as carefully as the conditions to the northward. By widening the area of study, as in the daily charts of the Indian monsoon area, a first step was taken in the proper study of the causes of the two monsoons, but Mr. Eliot has gone farther by adding a comparison of the conditions that simultaneously prevail over Europe, the Mediterranean, Persia, and Abyssinia. Such studies are analogous to those that have been made on a larger scale at the Weather Bureau by means of the great system of international observations and charts published between 1878 and 1887 and which have been kept up in a modified form since then. These charts of the whole Northern Hemisphere force us to take a broad view of the general circulation of the atmosphere and its direct influence on local conditions. The following is an abstract of Mr. Eliot's results:

In India the year may be divided into seasons, as follows: (1) the northeast monsoon, from December to February; (2) the transition, March to May; (3) the southwest monsoon, June to September; (4) the transition, October and November. During the northeast monsoon cold weather storms, with rain or snow, prevail, and, with regard to these, Eliot shows that they almost invariably originate over the plateau of Persia or in Beloochistan, or northwestern India. They travel toward the east or east-southeast at the rate of 15 or 20 miles per hour; they have moderate winds compared with the storms of the southwest monsoon; they bring the moderate rain essential for the cold-weather wheat and other crops of northern India, and are the chief sources of the snowfall of the western Himalayas; hence their economic importance and the necessity of issuing seasonal forecasts, if possible. If the northeast storms could be traced backward to the Mediterranean Sea and Europe, then the daily weather maps of that region should give the means of predicting the storms of India; but a study of those maps does not show a single case where such connection can be clearly made out. With perhaps one exception the cold-weather storms of 1893 started in the plateau of Iran during the prevalence of strongly-marked and persistent anticyclonic conditions north and west of that region, viz, in southeastern Europe, and it is probable, therefore, that these are the conditions most favorable to their formation. With very rare exceptions the cold-weather storms of India are not the continuation of European storms. It is almost certain that the annual snowfall of the Himalayas north of Cashmere, Punjab, and the northwest provinces is received almost entirely during the northeast monsoon, and that little falls during the southwest monsoon. The winter supply, which at some stations amounts to 50 feet, is almost certainly sufficient for the summer and autumn melting.

During the southwest monsoon season a complete change in winds and pressures takes place over the Indian Ocean, such as has no parallel elsewhere on the globe. The trough or belt of low pressure near the equator disappears; the tropical belt of high pressure north of the equator also disappears; the areas of northeast trades and of equatorial calms also disappear. The southeast trades of the Southern Hemisphere extend northward across and beyond the equator. On their western border, as they turn toward the northeast, they strike Abyssinia and even the coast of Arabia, and thus become the southwest monsoon winds of the Arabian Sea; on their eastern border they flow from Australia parallel to Sumatra, and, turning as they cross the equator, become the southwest monsoons of the Bay of Bengal. There is, therefore, a region, covering at least 30° in latitude and 70° in longitude, over which the motion of the lower atmosphere is completely changed by the transition from winter to summer. On comparing this great area with the much smaller land surface of India, and, indeed, of southern Asia, we see that the heated air of India alone is not likely to be the principal cause of the atmospheric disturbance. Mr. Eliot, after quoting the views of several eminent meteorologists, and after a detailed examination of the maps for each month of the year 1893, shows that the change called the "burst of the monsoon," or the sudden change from dust, dryness, and heat to moisture, coolness, and rain commences first in southern India, and advances northward, as it also advances from the coast districts into the interior. The rate of advance varies from year to year, and is sometimes effected in the course of a few days over the whole of India. In 1893 it occupied about two weeks, between the second and fourth week of June. The hottest period of this year in northern and central India was that from May 15 to May 21, or immediately preceding the burst of the monsoon in southern India. At this time the pressure in northern India was decreasing by a series of oscillatory changes, while the pressure at Zanzibar and over the Gulf of Arabia, was quite steady. During the third and fourth weeks of May, 1893, pressure increased about 0.05 at Zanzibar, and also at the Seychelles; the winds in the equatorial regions strengthened, and, finally, having passed the stage of unstable equilibrium, a strong current advanced northward toward India, with rainy, squally weather at its front. This change was completely effected during June, and then became permanent for the next three months. By June 21 the southwest monsoon was fully established over the Indian land and sea areas. After this the pressure was not so much lower in India, but was decidedly higher in the equatorial and south Indian Ocean. Before the burst of the monsoon the isobars ran parallel to the east and west coasts of southern India, but after that date they ran from east to west, or across the coast lines, and nearly parallel to the lines of latitude. Before the monsoon the isobars were largely the result of thermal conditions in the interior of India, but during the monsoon they were more directly related to the prevalence of the strong, steady, and massive southwest current. This latter distribution of pressure is clearly not the product of the antecedent or the actual thermal conditions in India proper.

By tracing the southwest monsoon back to the equator, and beyond, Mr. Eliot discovered that the flow of the current across the equator in 1893 increased rapidly in strength and steadiness in June and was strongest and steadiest in July; it thence decreased in both respects, rather slowly in August and rapidly in September, becoming weak and unsteady at the commencement of October. The fluctuations in the air current across the equator were related directly to the distribution and amount of the rainfall in India; in general, the rainfall was heaviest and most general when the air currents across the equator were strongest and *vice versa*. Any large variation in one was reproduced in the other. When the current was strongest in the equatorial belt and the Indian Seas and, consequently, while India was receiving its heaviest monsoon rains the weather in the equatorial belt was generally fine and skies were frequently clear for days and squalls were of comparatively rare occurence. There is, therefore, an inverse relation between the rainfall in India and in the equatorial belt, more especially its western half. The steadiness of the winds in the equatorial belt is as great as that of the monsoon flow into India across the coasts of Bombay and Bengal and, probably also as in the Arabian Sea and the Bay of Bengal.

So large a change in a great atmospheric current like that of the southeast trades over the Indian Ocean, by which, instead of ascending at the equator and flowing back as northwest upper trades, they are pushed across the equator and kept in the lower atmosphere until they ascend over Abyssinia and the Himalayas, can only be produced by the prolonged cumulative action of large forces. In 1893 two stages of change were recognized by Eliot, the first was preparatory, during which the ascensional movement over the equatorial belt was diminishing while the outflow toward the north was increasing. During the second stage, in consequence of increasing pressure in the extreme south, the ascensional movement diminished more rapidly and the whole mass of southeast trades was transferred northward by a continuous slow movement.

The western portion of the current across the equatorial belt which is, as a rule, strongest in July supplies aqueous vapor and rain successively to three large areas, namely: (1) the basins of the White and Blue Nile in Africa; (2) Hither India; (3) Birmah or Farther India. It is probable that prolonged, excessive rainfall in one of these areas will diminish the rainfall in the other. It is also probable that any large variations in the rainfall will accompany variations in the monsoon winds, and hence, also of the current across the equator. The monsoons are due to the invasion of India by moist southwest winds from the equatorial belt and not to a special hot weather local circulation of air set up in India by excessive temperature conditions. As the winds crossing the equator in August, 1893, were much more easterly than in June or July it followed that in August a larger proportion of the air was carried toward Abyssinia and the Upper Nile and less toward India. Possibly the weakness of the winds and lightness of the rains in India were due to this defection toward Africa, and, in general, it appears plausible that a diminished rain in India proper may often be the result of a heavier rain in Abyssinia and the sources of the Nile. Mr. Eliot therefore compares the reports of flood level in the Nile, as given by Mr. Willcock in U. S. Weather Bureau Bulletin No. 11, with the monsoon rainfall in India. The tabular data for this purpose are probably not directly comparable, but the suggested connection is plausible and very important, as we shall thus be able to connect the famines of Egypt and India with the movement of the air over the equatorial regions.

The suddenness with which the southwest monsoon bursts over India may be compared, in many respects, with the advance of those sudden changes of the weather with which we are familiar in America. The blizzards and cold waves of the United States and the pamperos of Brazil advance with well-defined fronts, and effect a complete change in the weather at any place within a few hours. From a mechanical point of view the most interesting feature is the steady increase of pressure in the southern Indian Ocean while the air over India becomes hotter with a relatively slight decrease of pressure. The intervening atmosphere thus passes through a stage of unstable equilibrium, but as soon as the gradient of pressure sets decidedly northward the air begins to move accordingly, and under the steady action of this gradient its motion is accelerated until the pressures are just able to overcome the resistance. When the advance of the southwest monsoon has brought it to the coast of Hindustan a decided increase of resistance is experienced, which holds it back for several days. J. Allan Broun, the founder of the mountain station, Augustia, has graphically described the view of this contest between the monsoon wind and the resisting land. (See Trevandrum Mag. Obs., Vol. I, p. 517, or Baird's Annual, 1876, p. 102.) In a week or so the increase of pressure in the south and the increasing temperature have combined to overcome this resistance, and the southwest wind pours over the Ghats into the interior of the country. The monsoon advances more rapidly over the interior than it formerly did over the ocean because this delay has given opportunity for an increase in the pressure gradients that determine its motion.

Phenomena similar to the bursting of the monsoon may undoubtedly be found developed, but perhaps on a smaller scale in any country where sudden changes from dry to moist weather occur, and Capt. D. Wilson-Barker points out that it is well known under other names in the Soudan and in Australia.

The pamperos of South America and the northers of the United States illustrate the case of large masses of air advancing horizontally against resistances which must be overcome by an accumulation of pressure in the rear. As the motions over land are resisted far more than over the ocean by the irregularities of the surface, and by the topsy-turvy movements during the warmer part of the day, therefore the accumulation of pressure in the rear or in the so-called area of high pressure, must be larger than in the case of the southwest monsoons of India. The southerly burster of eastern Australia seems to offer an analogous case.

From the essay on Southerly Bursters, by Henry A. Hunt of the Sydney observatory, it would appear that these occur most frequently during the warmer half of the year in the Southern Hemisphere, viz., from September to March, the maximum being in December. In all cases these bursters occur between an area of high pressure, south or west of Australia, and a low pressure, usually a deep depression, north or east of Australia. The high pressure is advancing toward the east or northeast, and the low pressure frequently stretches into a long trough or oval. If we compare these conditions in the Southern Hemisphere with those that occur in the northern, we find a mechanical similarity between the southerly winds of the burster and the northerly winds of our cold waves and blizzards. The principal difference is that due to temperature; for whereas our high pressures and northers occur in our winter season, and represent dry cold air flowing toward a warm moist region, the Australian burster occurs in the southern summer and represents cold moist air from the southerly ocean flowing over a continent where the air is dry and hot. In the American norther the surplus density of the northerly winds is due to their own dryness and low temperature, whereas in the Australian burster the surplus density of the southerly winds results from the deficient density of the very hot dry air over that continent. As the Australian continent is of about the same area as the United States, but has its center of figure about ten degrees nearer the equator, therefore, its average summer temperature is higher than ours. As it has no land to the south corresponding to the Dominion of Canada, therefore in its winter season it is colder than the Polar Ocean in its immediate neighborhood, but in its summer season its temperature is very much hotter than that of its Polar Ocean. Hence, Australia has no great winter blizzards, but has its southerly bursters in the summer time. The severity of the southerly or polar winds in Australia is modified very much by local conditions; thus, in western Australia the winds pass over comparatively level country, but in the eastern portion, the province of New South Wales, is traversed by a mountain range that checks the forward motion of the air until the increasing high pressure carries it over. In the basin west of these highlands the plains are highly heated by the sun and the hot surface air acquires a topsy-turvy circulation, until the high pressure on the west has accumulated sufficiently to push the air eastward over the coast range, which it accomplishes suddenly, while at the same time the southerly winds on the coast rushing inward produce the local gale at Sydney, known as a brickfielder or southerly burster. On the whole the burster is unfavorable to rain; it may bring a few showers to the coast but dry weather prevails in the western part of Australia. A well-developed area of high pressure, such as gives a typical southerly burster, lasting three days, has an axis extending 2,400 miles north and south, and it travels at the rate of 400 miles per day. Steady breezes attend it during the six days required by it to travel from west to east over the lowlands of Australia.

The areas of high pressure that bring bursters to Australia are but special single areas out of hundreds that pursue similar courses over the Antarctic Ocean, but do not happen to approach Australia. Their development and progress constitute integral parts of the so-called general circulation. Special features in the phenomena of bursters are due to local Australian conditions, but the general character of the high areas and the resulting general features of the bursters must be studied not in Australia, but over the distant oceans.

THE PRESENT CONDITION AND RECENT PROGRESS OF CLIMATOLOGY.

By Prof. Dr. W. KOEPPEN. (Extract from Geographische Zeitschrift, Vol. I, p. 617, etc.)

"In America there exists a well-organized system of observations. Notwithstanding this the study of the climatology of this continent is still beset with many difficulties. The extensive system of the U. S. Signal Service that is supplied with money to an extent entirely unknown for such purposes in Europe was originally so trimmed down to the needs of weather telegraphy and weather predictions that there was remarkably little left for climatology or even for science in general. Generals Hazen and Greely, the successors of General Myer, on the other hand, brought about a change by the introduction of scientific investigations, which, after 1891, found a wider official recognition in the transfer of this branch of the public service from military hands over to the Department of Agriculture. Even now, however, practical applications play the leading part in the programme of the new Weather Bureau, but among these the establishment of the climatic elements takes a prominent place. The treasures of observations and self-registers that have accumulated in a